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Chart of the Nuclides, Gamma Emission / Internal Conversion, Nucleonica

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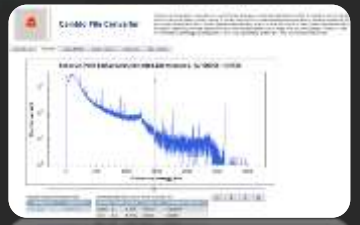
Chart of the Nuclides, Gamma Emission / Internal Conversion, Nucleonica

Overview

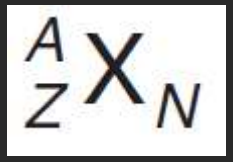
- Nuclide Charts
- Electronic Nuclide Charts
- Decay and Reaction Processes on the Nuclide Chart
- Karlsruhe Nuclide Chart
- Gamma Emission and Isomeric Transitions
- Internal Conversion
- Use of Nucleonica for Gamma Emisison Data



What is a nuclide?

A species of atom, characterized by its mass number A, atomic number Z and nuclear energy state (m or g), provided that the mean life in that state is long enough to be observable (IUPAC)

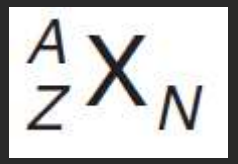
In general, an atom with atomic number Z, and neutron number N is known as a nuclide. A nuclide can be specified by the notation:



where Z is the atomic (proton) number, N is the neutron number, A is the mass number (A=N+Z), and X is the chemical element symbol.

Approximately 3000 nuclides are known, but only about 10% of these are stable. Nuclides with the same N and different Z are called isotones, and nuclides with the same mass number A are known as isobars.

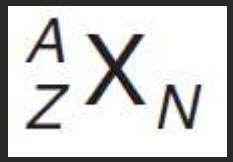
What is a nuclide?



Because of the relationships between *Z*, *A*, *N* (*A* = *Z*+*N*) and X, a nuclide can be uniquely specified by fewer parameters. A particular chemical element is uniquely specified by its symbol X or the proton number *Z*. A nuclide is uniquely specified by the element name X (or proton number *Z*) together with the mass number *A*.

An example is ^{60}Co which refers to the element cobalt (chemical symbol Co) with mass number 60 (number of protons plus neutrons). A variety of ways of referring to this nuclide are in current use i.e. Co60, Co-60, Co 60, ^{60}Co, and cobalt-60.

What is a nuclide?



Nuclide: Refers to a particular atom or nucleus with a specific number *N* of neutrons and number *Z* of protons. *A* is the mass number *(= Z +N)*. Nuclides are either stable or radioactive. Radioactive nuclides are referred to as radionuclides.

Atomic Number, Z: The number of positively charged protons in the nucleus of an atom.

Neutron Number, N: The number of neutrons in the nucleus of an atom.

Isotope: One of two or more atoms of the same element that have the same number of protons (isotope) in their nucleus but different numbers of neutrons. Radioactive isotopes are referred to as radioisotopes.

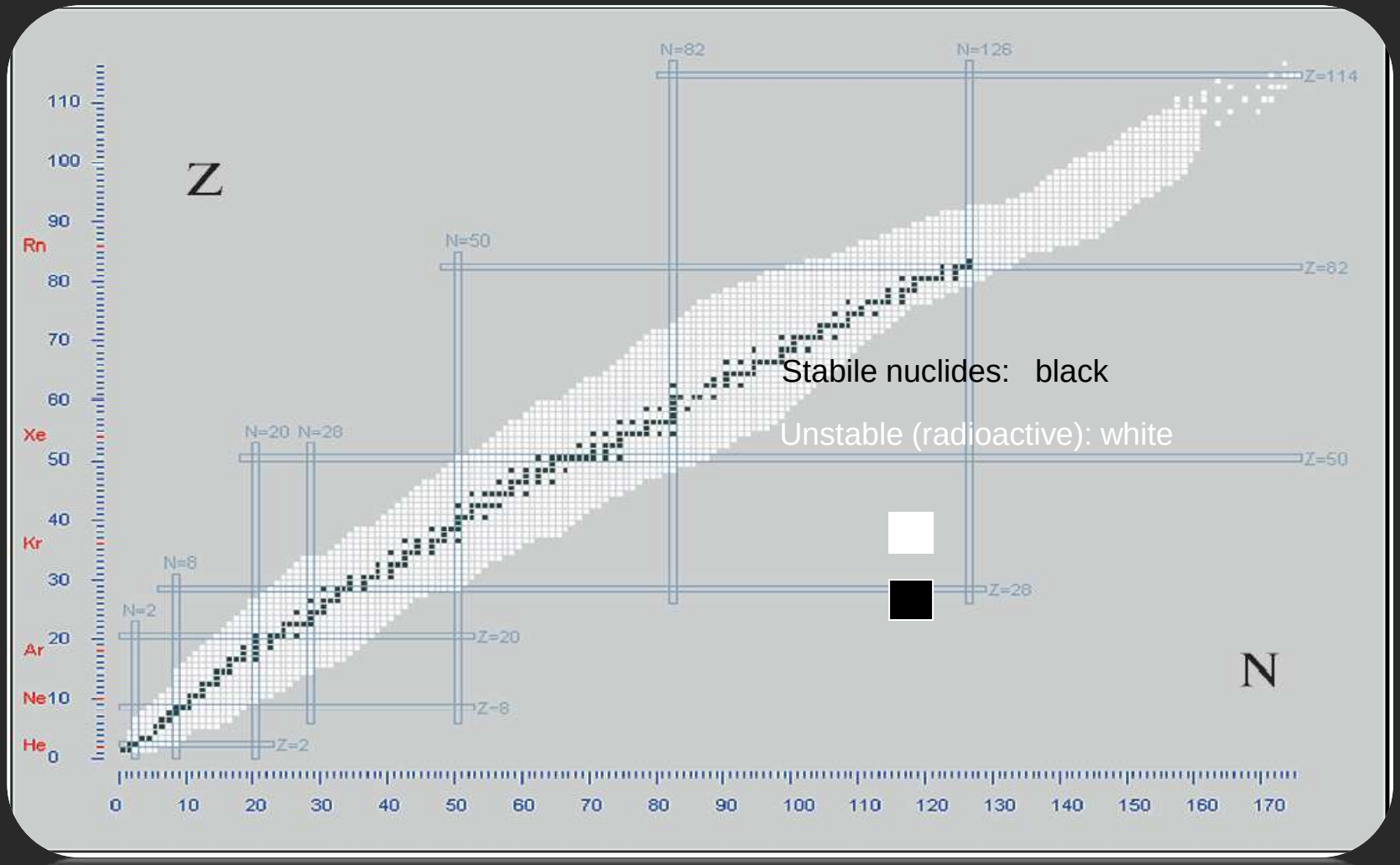
Isotone: One of several different nuclides having the same number of neutrons (isotone) in their nuclei.

Isobar: Nuclides with the same atomic mass number *A(= Z +N)* but with different values of *N* and *Z* e.g. ^{14}B, ^{14}C, ^{14}N.

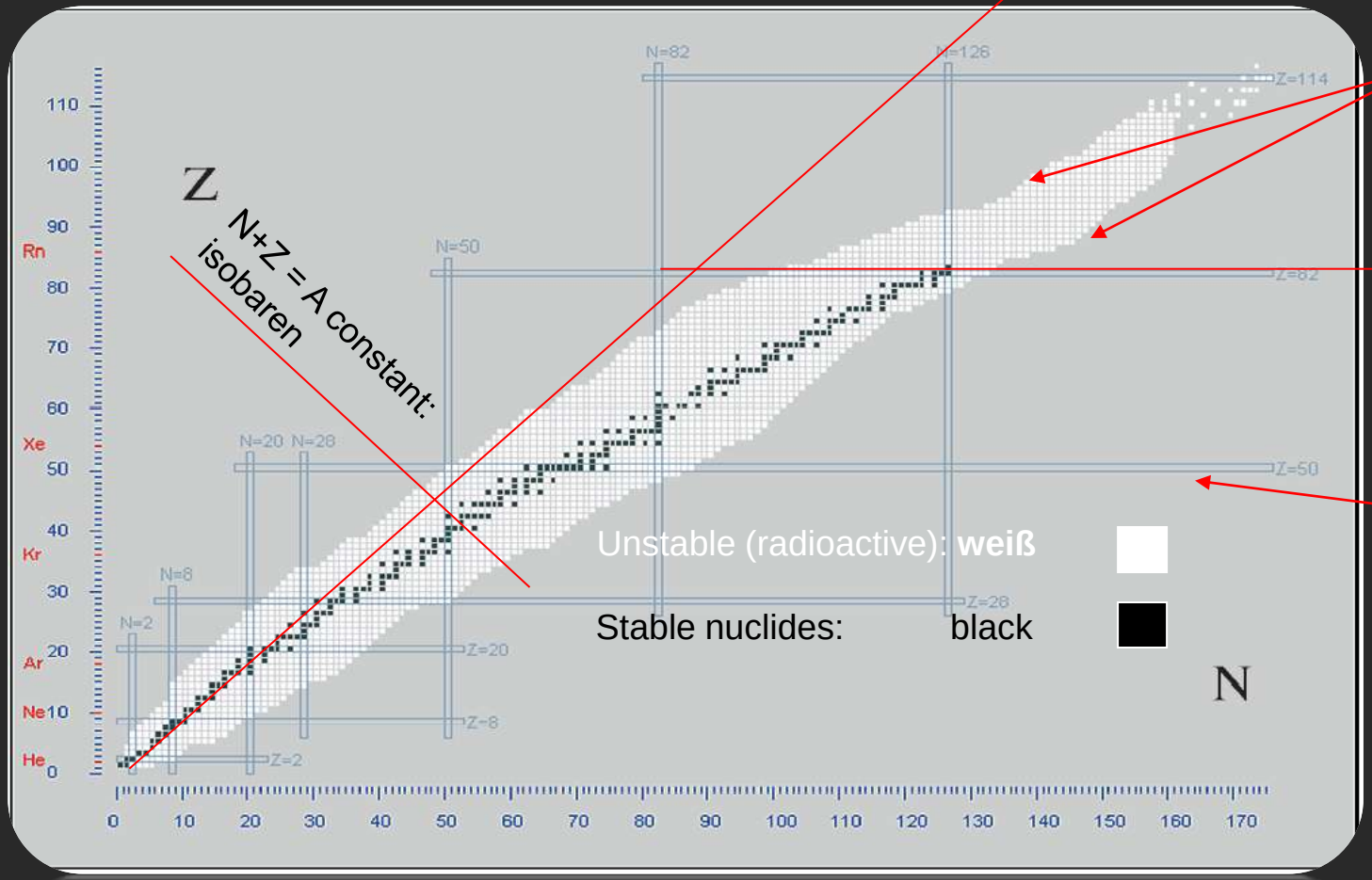
Isomer: Atoms with the same atomic number *Z* and the same mass number *A* in different long-lived states of excitation – the higher states being metastable with respect to the ground state. For example, an isomer of ^{99}Tc is ^{99m}Tc where the m denotes the long-lived excited state.

What is a Nuclide Chart?

What is a nuclide? A species of atom, characterized by its mass number, atomic number and nuclear energy state, provided that the mean life in that state is long enough to be observable.



What is a Nuclide Chart?



neutron drip-lines

Magic numbers

2, 8, 20, 28, 50, 82, 126

Z=50

Z = constant: isotopes

Electronic Nuclide Charts

There are a variety of “electronic” nuclide charts available on the internet. Each of these resources has its own particular tool for navigating the nuclide chart efficiently and displaying the data once a particular nuclide has been selected. These internet resources are restricted, however, to only displaying nuclear data.

The main ones are listed below.

- Korea Atomic Energy Research Institute KAERI http://atom.kaeri.re.kr/
- Japanese Atomic Energy Research Institute (JAERI), http://wwwndc.jaea.go.jp/CN10/
- The Lund/LBNL Nuclear Data Search, http://nucleardata.nuclear.lu.se/Database/toi/.
- IAEA’s Nuclear Data Centre, http://www-nds.iaea.or.at/
- Nucleonica (Nuclide Explorer) www.nucleonica.com

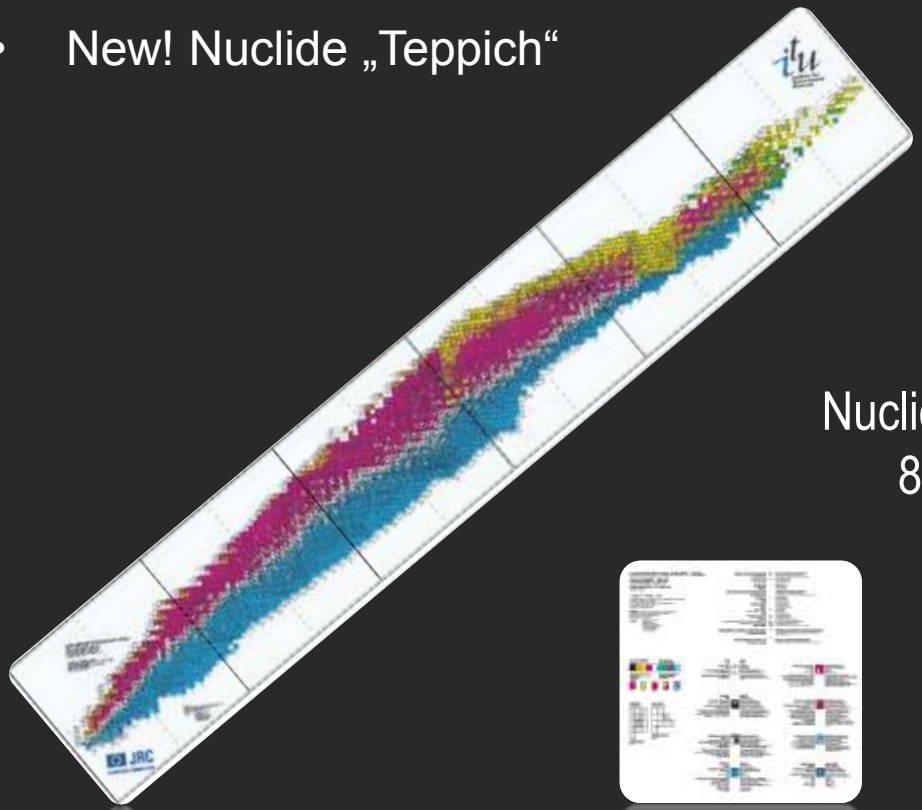
Karlsruhe Nuclide Chart …

It all started with the Karlsruhe Nuclide Chart …

http://www.KarlsruheNuclideChart.net

Karlsruher Nuklidkarte …

- New! 2009 Druck der Broschüre + Faltkarte
- New! 2010 Druck der Wandkarte
- New! Nuclide „Teppich“



Nuclide „carpet“
8m!

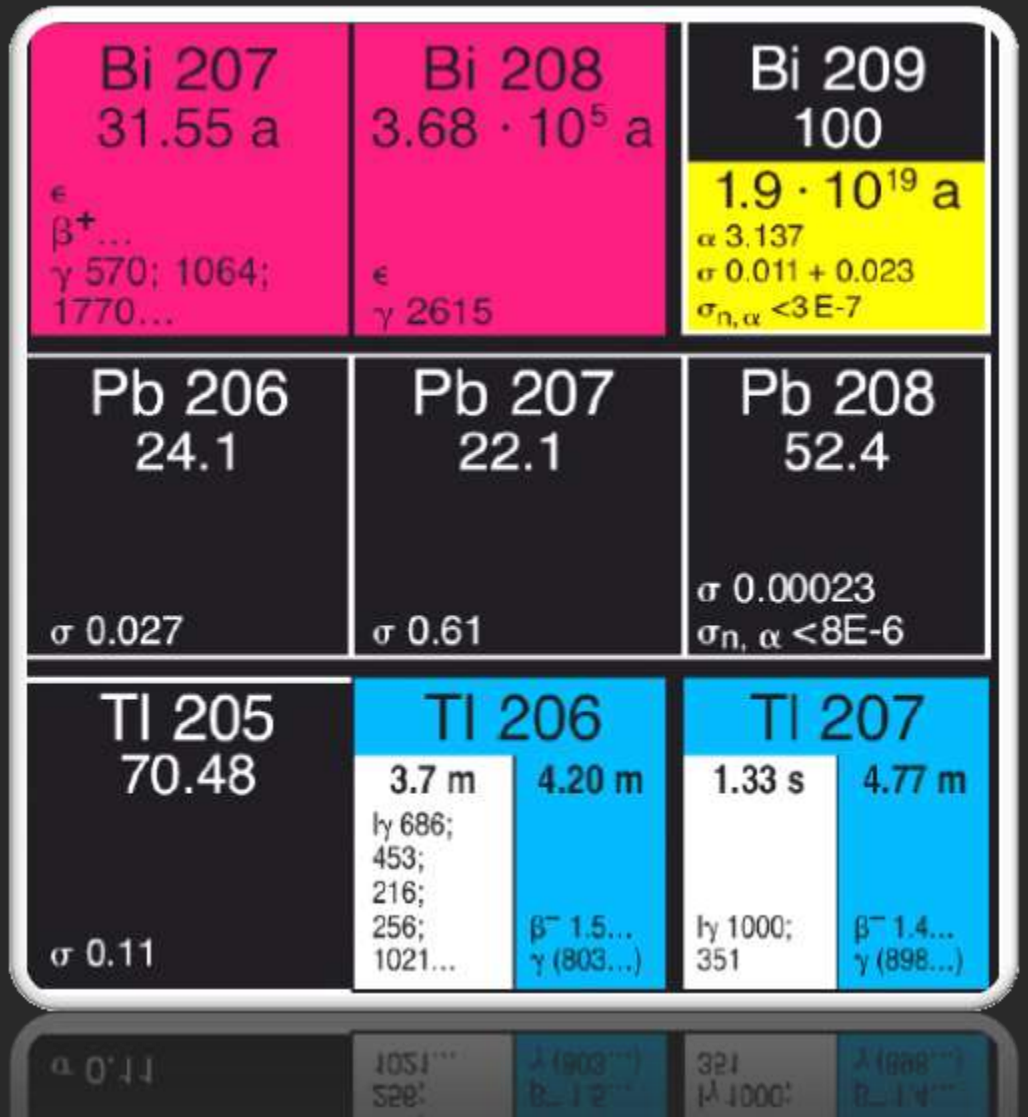
2008

Explanation of the Karlsruhe Chart of Nuclides

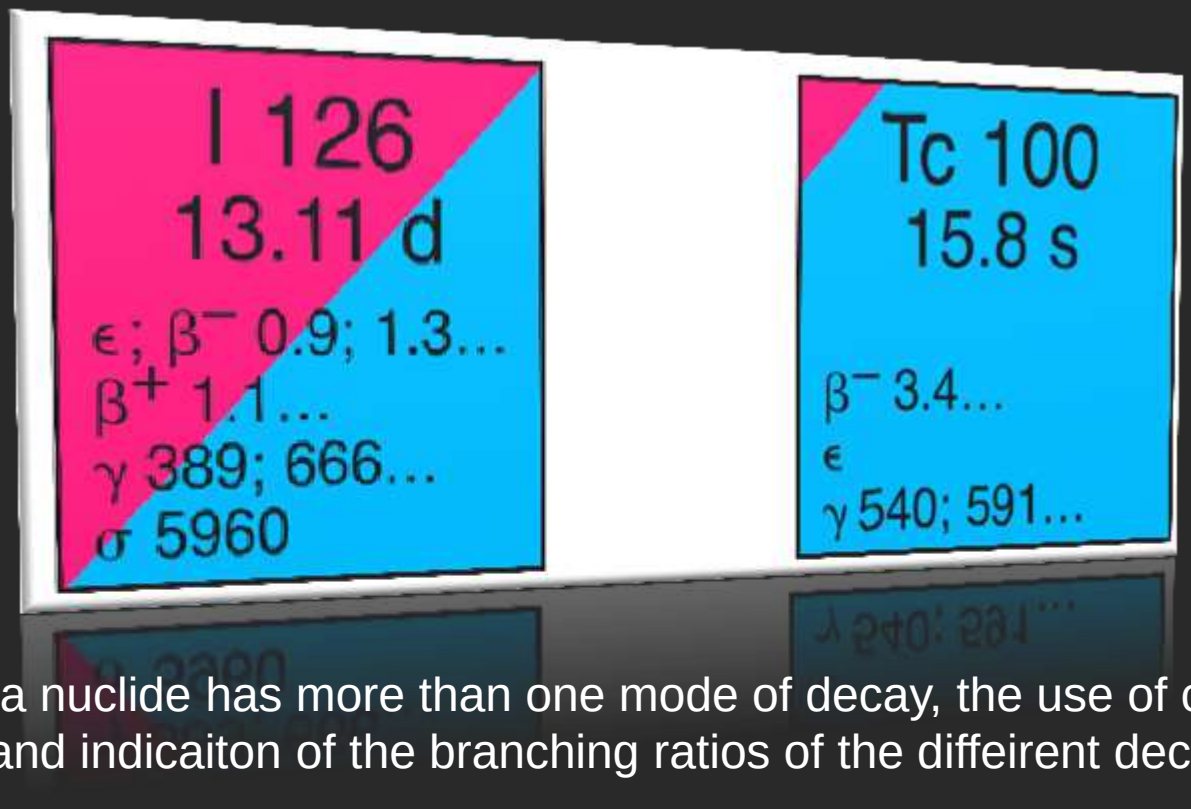
Use of Colours in the Nuclide Chart :

The Karlsruhe Chart of the Nuclides showing the colours used to indicate the decay modes:

- black = stable nuclide
- yellow = α-decay
- red = β+-decay or electron capture;
- blue = β--decay;
- white = isomeric transition).



Multiple Decay Modes and Branching Ratios

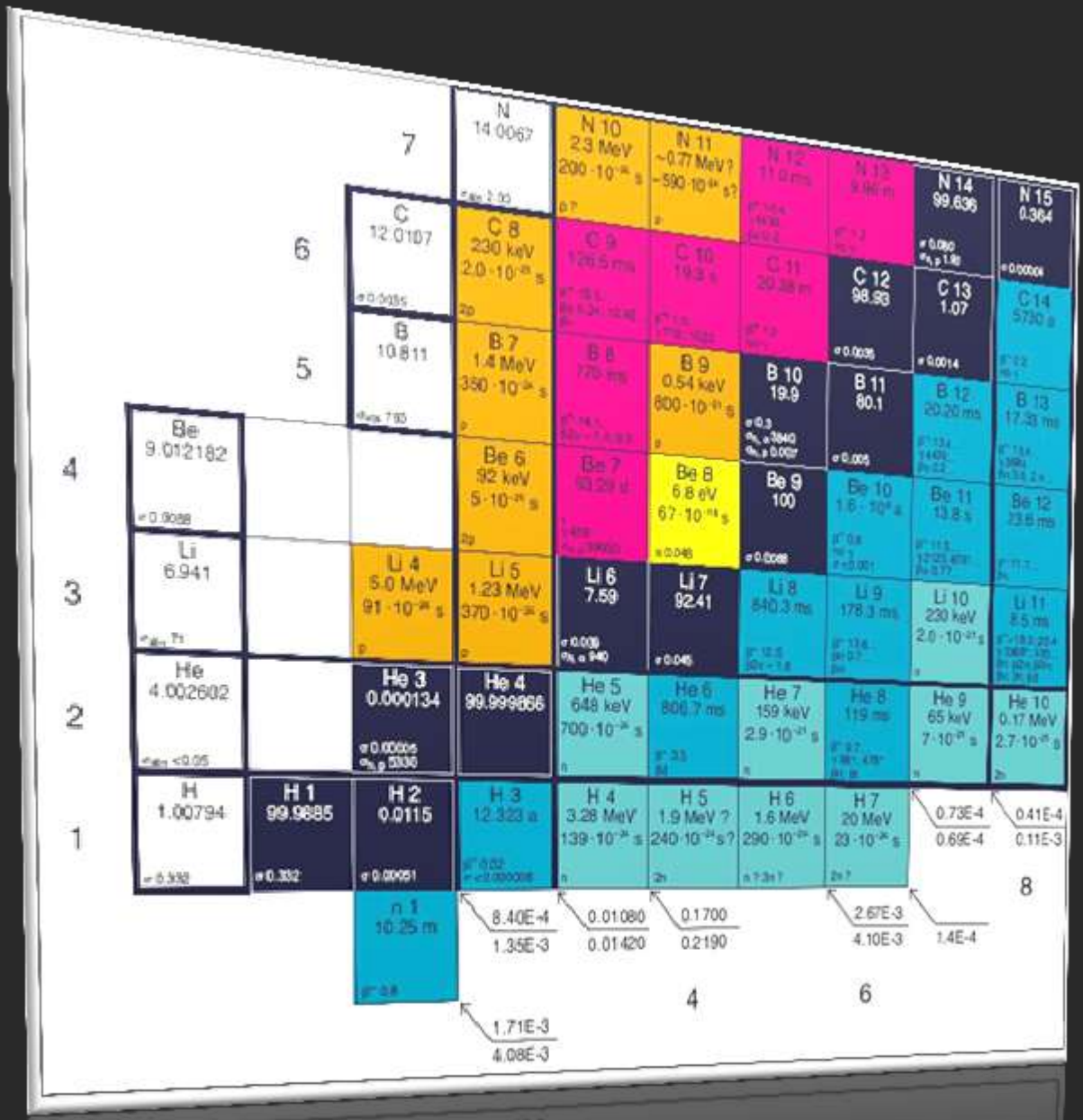


When a nuclide has more than one mode of decay, the use of coloured triangles gives and indicaiton of the branching ratios of the diffeirent decay modes.

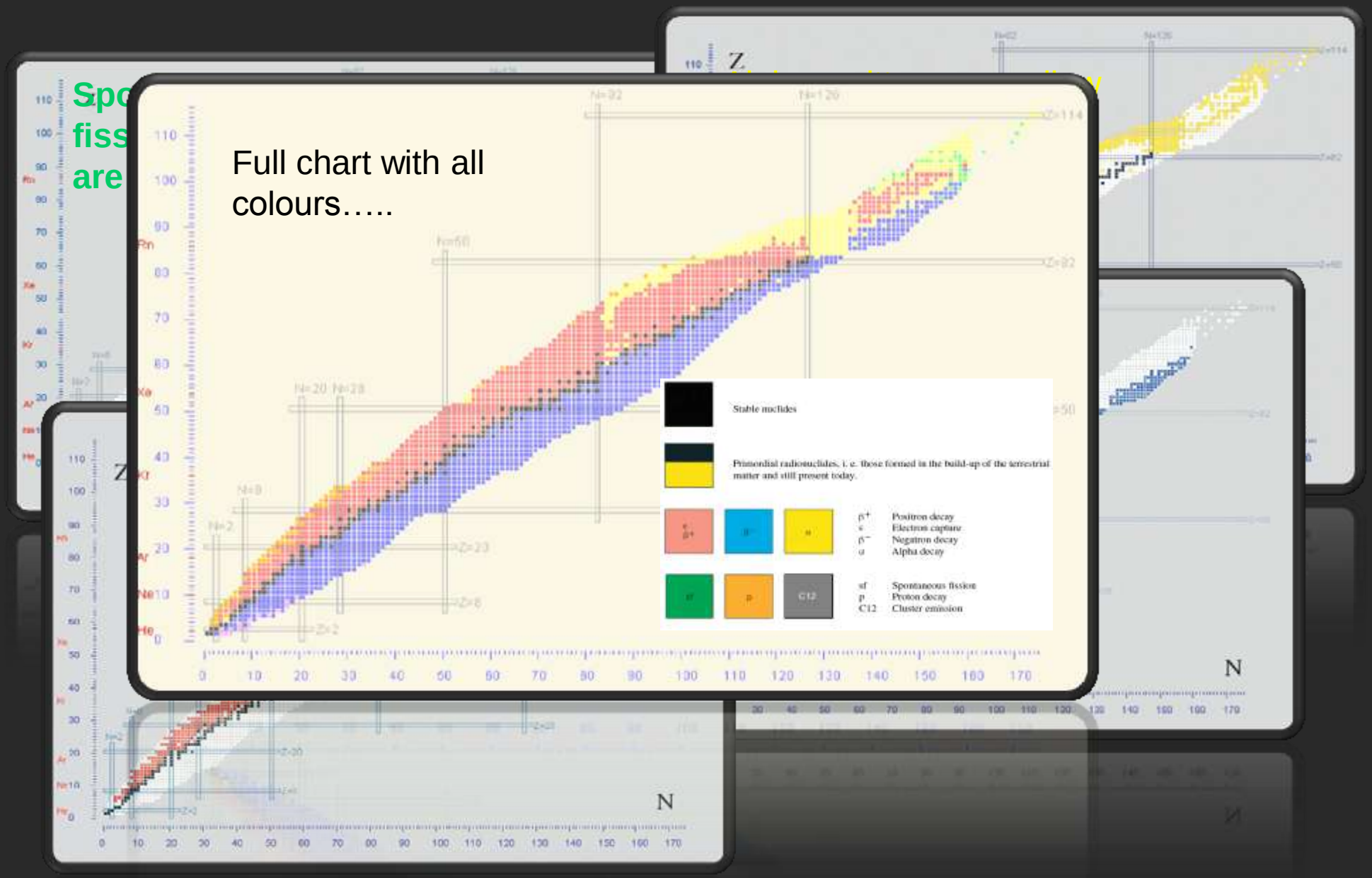
Left: The large triangles in I-126 indicates that the brnching ratios for electron capture and beta emission are ≥ 5 %, but ≤ 95 %.

Notice that the order of the branching ratios in the text box indicates the mosts improtatn ,second most importe etc.

Right: The small triangel in Tc-100 indicates that ε branching ratio ≤ 5 % ist. The corresponding value for ß⁻ emission ≥ 95 %.

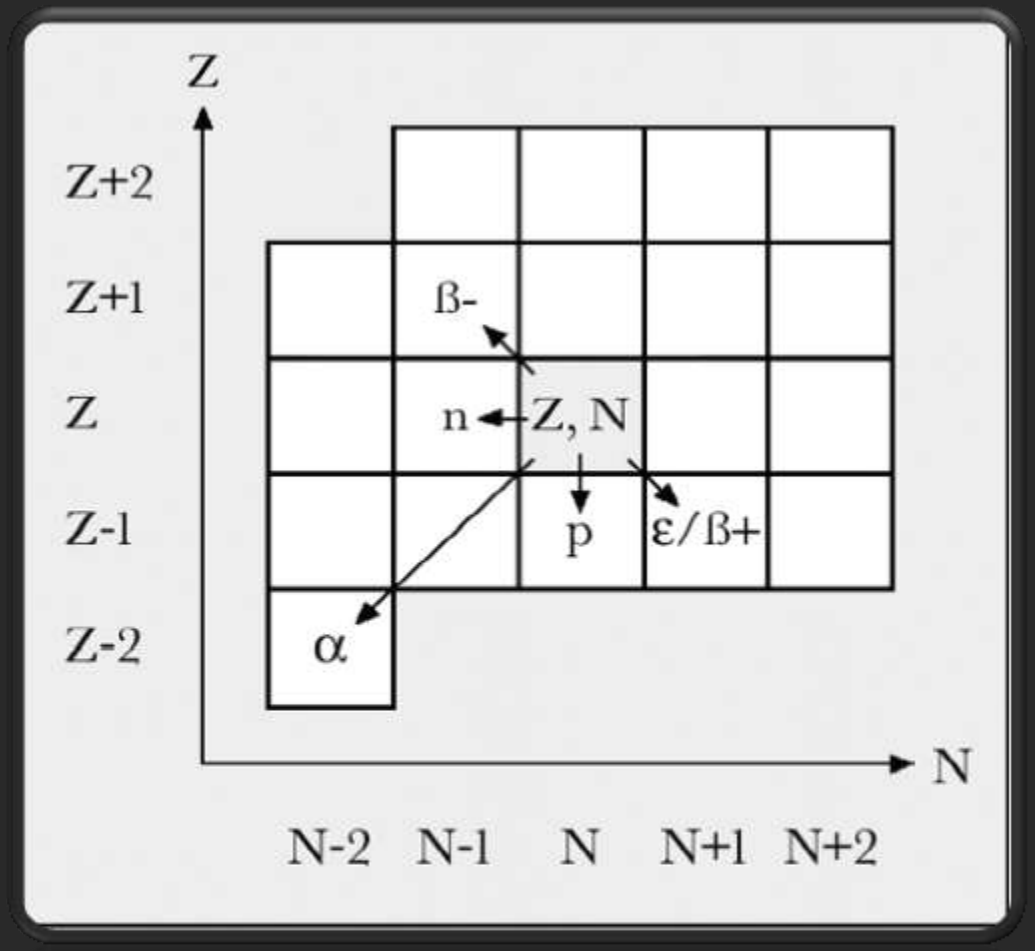

7
6
5
4
3
2
1
N 14.0067
C 12.0107
B 10.811
Be 9.012182
Li 6.941
He 4.002602
H 1.00794
N 10 2.3 MeV
N 11 ~0.77 MeV ?
N 14 99.636
N 15 0.364
C 8 230 keV
C 12 98.93
C 13 1.07
C 14 5730 a
B 7 1.4 MeV
B 9 0.54 keV
B 10 19.9
B 11 80.1
B 12 20.20 ms
B 13 17.33 ms
Be 6 92 keV
Be 8 6.8 eV
Be 9 100
Be 10
Be 11 13.8 s
Be 12 23.6 ms
Li 4 5.0 MeV
Li 5 1.23 MeV
Li 6 7.59
Li 7 92.41
Li 8 840.3 ms
Li 9 178.3 ms
Li 10 230 keV
Li 11 8.5 ms
He 3 0.000134
He 4 99.999866
He 5 648 keV
He 6 806.7 ms
He 7 159 keV
He 8 119 ms
He 9 65 keV
He 10 0.17 MeV
H 1 99.9885
H 2 0.0115
H 3 12.323 a
H 4 3.28 MeV
H 5 1.9 MeV ?
H 6 1.6 MeV
H 7 20 MeV
n 1 10.25 m
8.40E-4
1.35E-3
0.01080
0.01420
0.1700
0.2190
2.67E-3
4.10E-3
1.4E-4
0.73E-4
0.69E-4
0.41E-4
0.11E-3
8
4
6
1.71E-3
4.08E-3

What do the colours mean?…



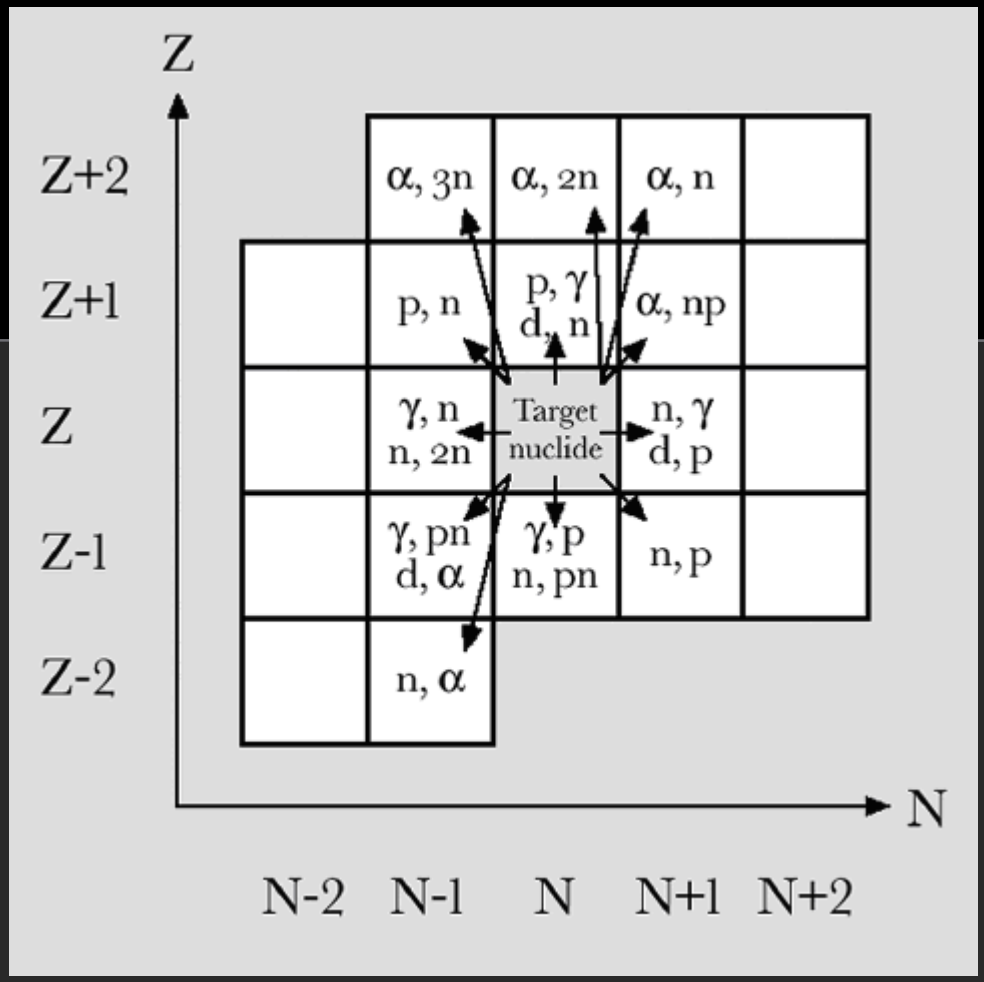
Radioactive Decay…

Nuclear decay processes on the nuclide chart. A nuclide with “co-ordinates” *Z, N* transforms to the nuclide *Z’, N’* through the decay processes shown;

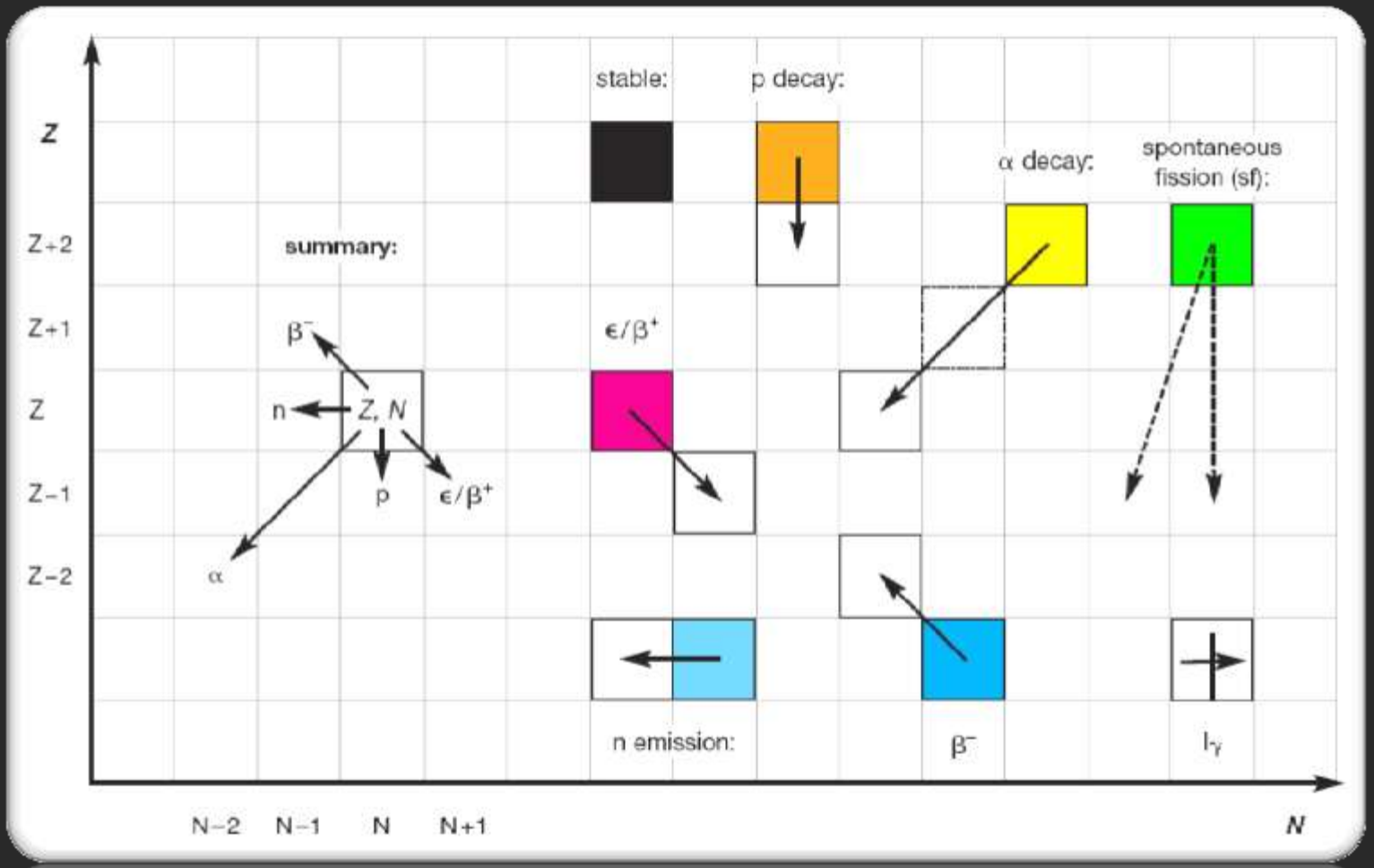


Activation Process and Nuclear Reactions…

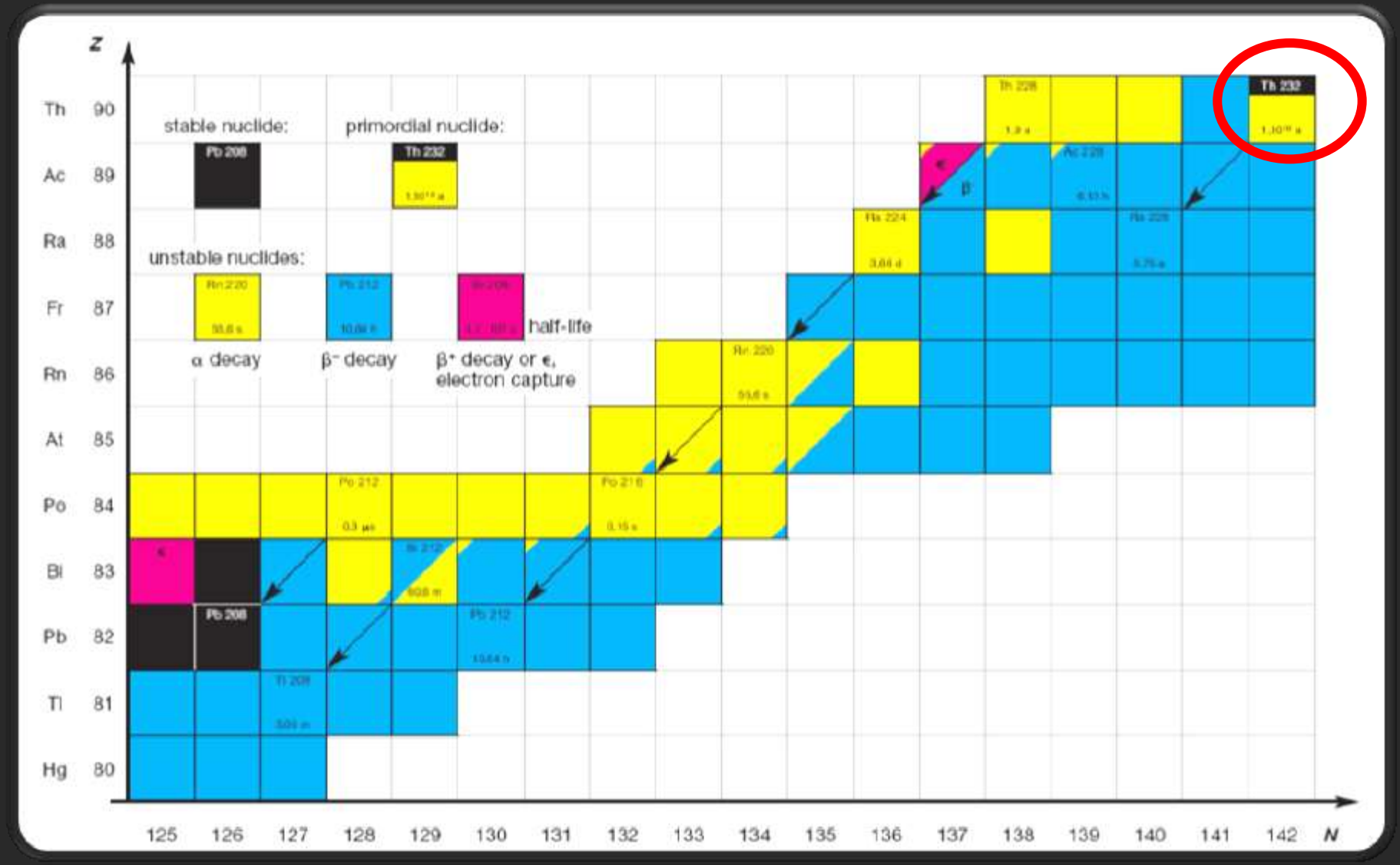
Activation processes and nuclear reactions on the nuclide chart. A target nuclide with co-ordinates *Z, N* transforms to the nuclide *Z', N'* through the processes shown



Radioactive Decay…



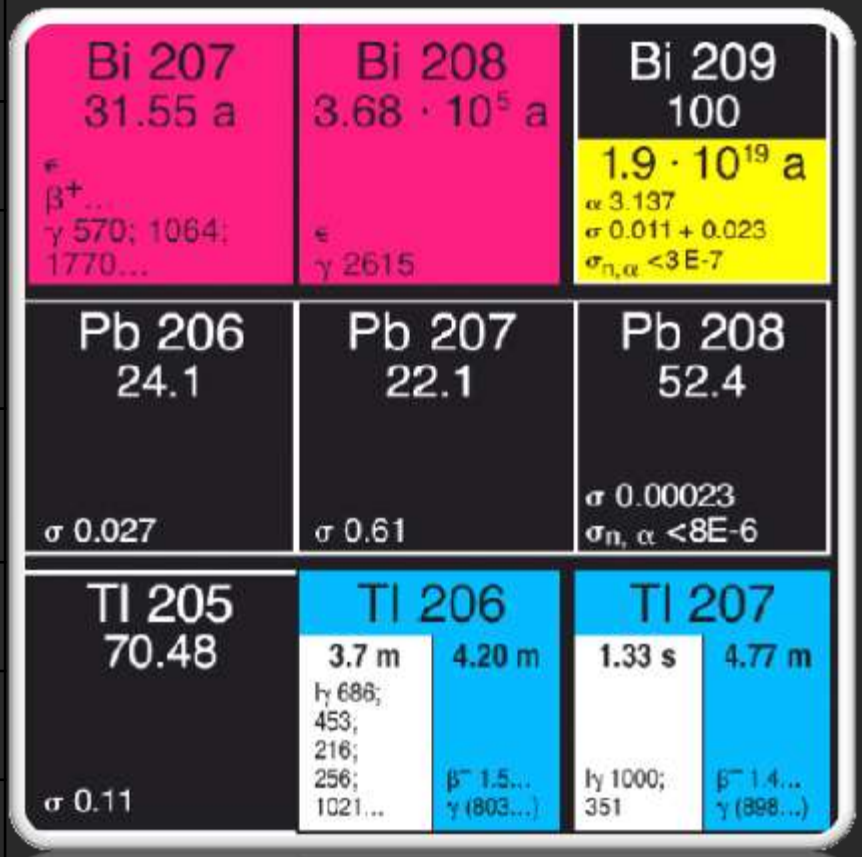
Karlsruhe Nuclide Chart: Th232 Decay



Gamma Emission and Isomeric Transition (Iγ)

Table 1: Notation used for gamma emission data in the Karlsruhe Nuclide Chart

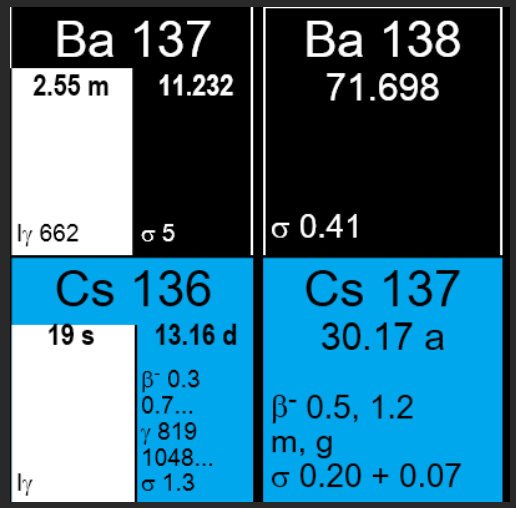
The data given in the left part of the nuclide box apply to the metastable state, those in the right part to the ground state. Iγ denotes γ-quanta due to the decay to the ground state of the same nuclide (isomeric decay).	
Points indicate further transitions of the same type with lower intensities.	…
Energies are given in keV for γ-quanta, in MeV for all kinds of particles. A radiation symbol without energy value indicates that the radiation occurs but the energy has not been measured.	
Energies of the strongest γ-quanta arranged in order of decreasing intensities. Intensities less than 1% are given in brackets.	γ 815, 1711… γ (1340)
γ-Energies followed by an asterisk denote transitions after β-delayed particle emission.	γ 815*
Several γ-quanta of unknown intensities within the energy interval 291-1319 keV.	γ 291-1319
Conversion electrons are specified only if they are more probable than the γ-quanta. Energies are not quoted.	e⁻



Internal Conversion

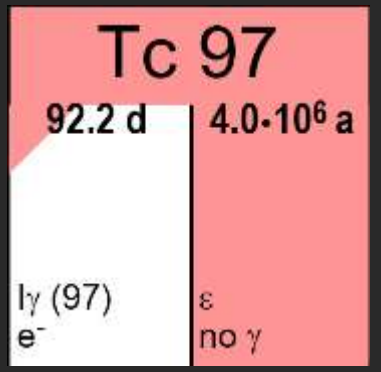
Alternative to gamma emission, the excited nucleus may return to the ground state by ejecting an orbital electron. This is known as internal conversion [4] and results in an energetic electron and X-rays due to electrons cascading to lower energy levels. The ratio of internal conversion to gamma emission photons is known as the internal conversion coefficient. Conversion electrons are mono-energetic.

Consider the decay of the isomeric state ^{137m}Ba. This nuclide emits a 0.661 MeV photon which undergoes internal conversion in 11% of the transitions. These conversion electrons are seen in the beta spectrum of ^{137}Cs.

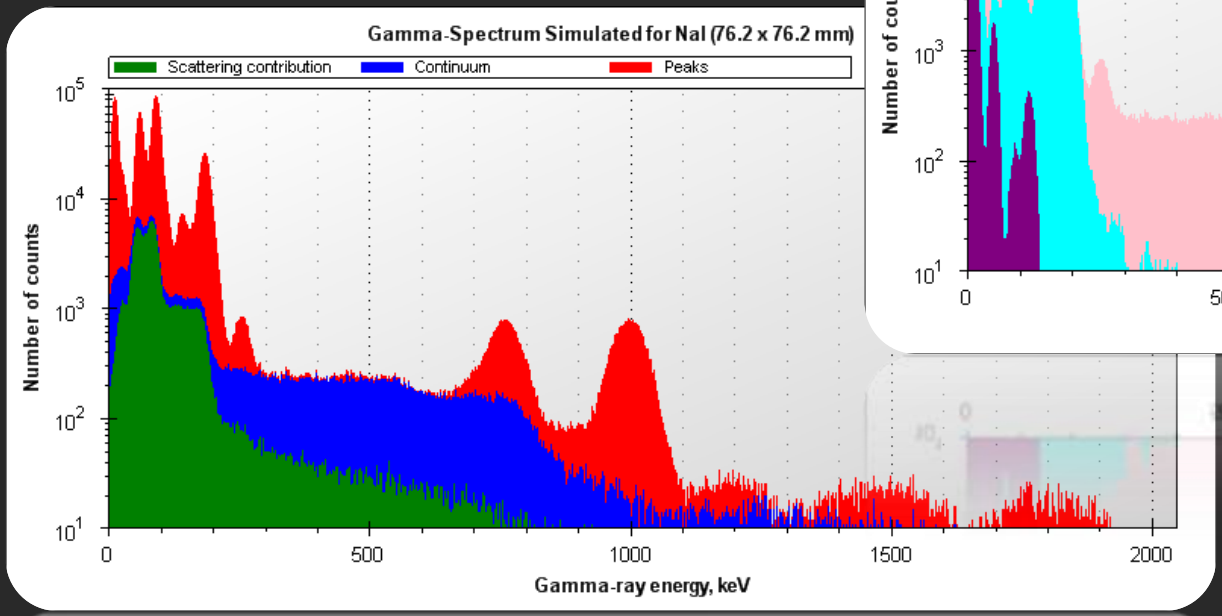


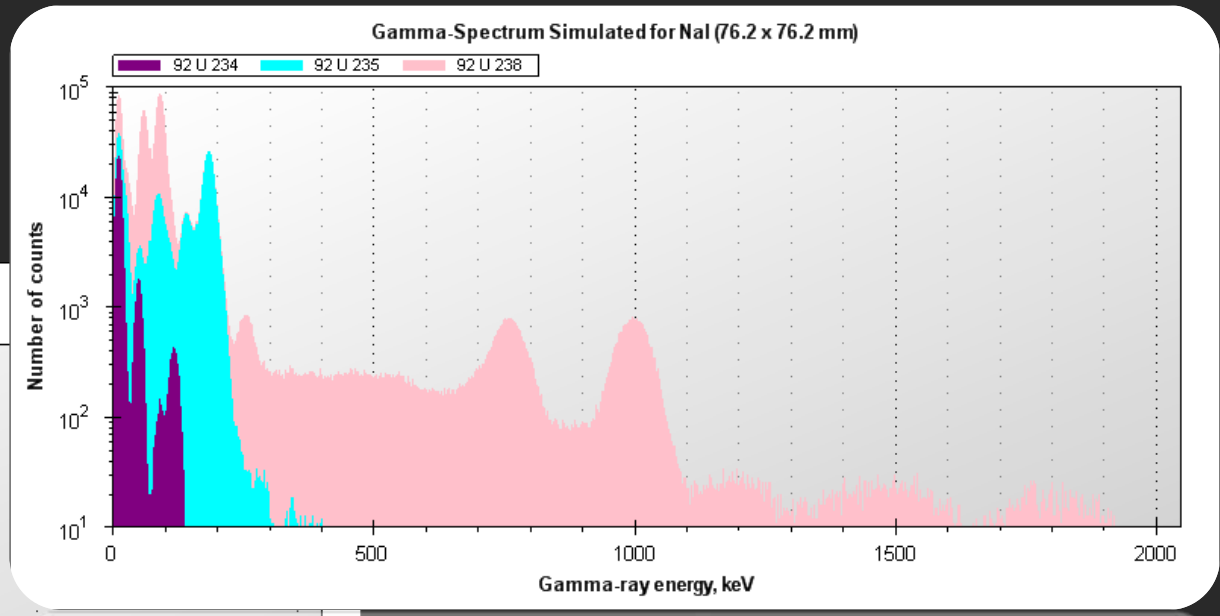
Following the internal conversion, outer orbital electrons fill the deeper energy levels and result in characteristic X-ray emission. The X-rays can in turn lead to the ejection of outer electrons through an internal photoelectric effect. The low energy ejected electrons are known as Auger electrons.

Internal Conversion Coefficient: is defined as the ratio of the number of de-excitations via electron emission to the number of excitations via gamma emission.



Conversion electrons are specified (see examples Cs137 and Tc97 if they are more probable than the gamma quanta (energies are not given)





The *γ*-spectrum modelled for a 10-year-aged natural U sample and 3"×3" NaI detector. The two diagrams show different presentations of the same spectrum. The top diagram shows the separate contributions form the parent and daughters of U-234, U-235, U-238. The bottom diagram shows the contributions from the peak and continuum components of the spectrum.